were extended from Norfolk to Eastport. The subsequent history of this storm will form a part of the March Review.

From the point of view of the forecaster the failure of southern lows to advance into northeastern districts was one of the features of the month, notably in connection with lows Nos. III, VI–A, VII, and IX, which seemed to be marked for the southern New England Coast but moved off to sea over the Atlantic. These failures to move to the northeast are now believed to have been due to the obstruction presented by New England highs; and the precept to be drawn from the failures is that a low will not move into a region that will be occupied on the morrow by an incoming high. The forecaster must distinguish between a high in situ and an incoming high. The reason back of this is that with an incoming high, as in the case quoted, the winds would be from the north or northwest, with falling temperature; conditions inimical to the development and sustenance of a low.

STORM WARNINGS DURING FEBRUARY, 1914.

More than the usual number of severe storms visited the North Atlantic Coast. Warnings were issued on the 6th, 7th, 10th 13th, 14th, 16th, 20th, 23d, 25th, and 28th. On the Pacific Coast the main storm period occurred between the 17th and 22d. Warnings were issued on these dates, and also on the 23d, 26th, and 28th.

The Gulf Coast was not visited by severe storms, although warnings for high northwest winds were displayed on the 6th and 23d.

THE VALUE OF WEATHER FORECASTS IN THE PROBLEM OF PROTECTING FORESTS FROM FIRE.

By EDWARD A. BEALS, District Forecaster.

[Dated Weather Bureau, Portland, Oreg., Nov. 29, 1913.]

Climate is defined as the sum of weather conditions affecting animal and plant life, and as trees come under the head of plant life, they are affected by climate from whatever point of view the cause and effect of climate in connection with forests may be considered. The integral elements of climate are the general atmospheric conditions, or in other words the weather from day to day, and it is the purpose of this paper to show whether or not advance information about the weather can be used to advantage in reducing the fire losses in forested areas.

Weather forecasts are not accurate, nor will they ever be, no matter how perfect the method by which they are made. They are the product of the human mind, which is liable to error in every walk of life. Mistakes are sometimes made in the transmission of forecasts, and sometimes they are wrongly interpreted; while we can not expect perfection, it is safe to expect the forecasts to be verified about five times out of six, and in some special lines, such as warnings of floods and storms, the percentage of accuracy is even greater than this.

Weather forecasts are made in the expectation that those receiving them will be able to protect their interests when threatened by adverse weather, otherwise they are of no special benefit to anyone. It would do no good to warn a vessel of a coming storm if that vessel could not avoid it or was so constructed that she could not take in sail, batten down her hatches, and securely lash movable articles to the best advantage. Neither would it do any good to advise a farmer of a coming frost if he were unprepared to protect his crop. It would only be giving him cause to worry before the damage was done, and as worry is said to shorten life he should be saved from as much of it as possible.

Trees according to their species require heat and moisture in variable quantities. There is a maximum, a minimum, and an optimum of both elements for each species which varies with the season of the year. Forests are subject to serious injury if the winds are strong enough to blow down a large number of trees before they are matured. If known beforehand that a forest is threatened by damaging extremes in temperature, precipitation, or wind, no economic protective measures could be taken to avert the danger, and it would suffer according to the extent and character of the subsequent weather, however severe it might be.

Damage by extremes in temperature, precipitation, or wind is not great when compared with the damage done by fire that is fanned by winds of moderate force. Preparedness against fire can be taken in all forested areas by increasing fire patrols, putting out smouldering fires, and shutting down dangerous logging operations for a short period; therefore if winds favorable for spreading forest fires can be foretold the information would be of great benefit to all concerned in the preservation of forests.

Droughts and periods of hot weather contribute to the fire hazard, but these conditions alone do not necessarily portend the occurrence of a great fire, as without wind an incipient fire would spread slowly and could soon be extinguished by modern fire-control methods. In quiet air a fire causes inflowing currents that might attain a surface velocity of 20 miles or more if the fire was intense and not too limited in extent. These inflowing winds would operate to check spreading, except as large embers were carried aloft, and after leaving the vortex drifted slowly to a distance before coming to the ground. In such cases a new fire would be started, and if there were many such embers, and they were not promptly extinguished, the fire might burn over a large area.

Usually after a period of hot, still weather we can look for increasing winds, and if the period of hot weather has been attended by drought conditions are most threatening, and it is then that reliable wind forecasts could be used to good advantage. The problem of making them is extremely difficult, much more so than the predicting of stormy winds along our sea coast, owing almost if not wholly to the fact that the sea is level and the forests are generally located in a hilly or mountainous country. Over the sea the winds follow the pressure gradients with uniformity, while over the land, especially in mountainous countries, they are deflected by topography to such an extent that at times it is impossible to recognize their relationship to the pressure gradients, either as regards force or direction.

Winds causing the spread of forest fires may be divided into three classes in the order of their importance, as follows: Cyclonic winds, mountain and valley breezes, and winds having monsoon characteristics. All three classes may prevail at the same time, and they act and react on one another in a most confusing manner. Our largest and most destructive forest fires occur when cyclonic winds are the dominating feature over a large area, and especially when they cause foehn or chinook conditions on the leeward side of mountains. By cyclonic winds reference is made to those caused by a large atmospheric disturbance wherein the winds blow systematically, and they may be associated either with a cyclone or an anticyclone.

Winds of monsoon character prevail near the sea, and they can not be traced more than 100 or 200 miles into the interior of the United States. They are nothing more than magnified sea breezes, whereby during the height of the summer season the sea breeze has acquired such proportions that all the potentiality of the land breeze is expended in lessening the force of the sea breeze, which dominates both day and night, but with diminished velocity at night. It is for this reason they are characterized as monsoon winds instead of sea breezes.

In summer, monsoon winds prevail along the Pacific coast and at times in the Gulf States, but seldom if ever are they observed in the Atlantic States. Near the Great Lakes and along the Atlantic coast land and sea breezes modify the character of the winds for short distances inland, but ordinarily these winds are of such inferior strength as to be negligible quantities when there are forest fires within their confines.

The greatest complications are caused by mountain and valley breezes, and our geographical knowledge of them is meager. They blow up the valleys during the day and down them at night, but in some localities exceptions occur and the mountain breeze blows down the valley in the daytime. Winds of the latter character are regularly observed at the foot of glaciers on warm days, and they may become so strong as to be dangerous. These winds cease at night, and they reach their highest velocity shortly after noon. The cyclonic and monsoon winds may accelerate or retard the mountain and valley breezes, depending upon the angle in which the two forces meet.

As both monsoon winds and mountain and valley breezes are dependent upon the amount of insolation, convection, and radiation, their strength is reduced during cloudy weather, and they are modified to a greater or less extent when the atmosphere is hazy or smoky. During periods of clear and quiet weather in the open country mountain and valley winds may become violent in favorably situated canyons with wide openings, and their force and direction on all slopes is more or less controlled by the contour of the foothills and mountains.

As probably two-thirds of the nation's standing timber is in mountainous countries where mountain and valley breezes are the distinguishing features, a knowledge of their behavior is essential in forecasting the movement of the wind within a limited area, such as would be included within the boundaries of a forest fire occurring in these regions, even though it devastated several townships and of itself was considered a large fire. In other words, what to the lumberman would be a large area in consequence of the loss sustained, to the forecaster would be a small area in which to forecast exact conditions that are subject to modifications due to topography that he is familiar with only in a general way.

The weather forecaster can foretell within a reasonable degree of accuracy the general movement of the air over a large area, and it ought not to be difficult for the man on the ground, familiar with the behavior of the mountain and valley breezes in his neighborhood, to adapt such a forecast to fit local conditions. He should bear in mind that when the general forecast, which is based upon cyclonic conditions, indicates strong easterly winds that in nearly all valleys lying east and west the winds on the east side of a mountain would be accelerated during the daytime and retarded at night, and the reverse condition would prevail on the west side of the mountain. In transverse valleys modifications would ensue in direction and force, with the latter varying between the extremes occurring in the east and west valleys and the former guided by the contour of each valley. In localities where the mountain breeze blows down the valley in the daytime allowances would have to be made the opposite of those for the up-valley breezes. When other winds are forecast, local adaptations of a similar nature must be made for individual localities in order to overcome the discordances that otherwise are bound to occur.

The season for forest fires is from April to October, inclusive; they are most prevalent in September and of rare occurrence in June. In Forest Service Bulletin No. 117, on page 23, a list of historic fires is given, as follows:

TABLE 1.—*Historic forest fires in the United States and Canada.*

Date.	Name of fire.	Location.	Area burned.	Lives lost.
			Acres.	*Number.*
1825—October	Miramichi	Maine and New Brunswick	3,000,000	160
1837—(?)	Sebools	Maine	130,000	
1846—(?)	Yaquina	Oregon	450,000	
1853—May	Pontiac	Quebec	1,600,000	
1860—(?)	Nestucca	Oregon	320,000	
1868—September	Coos	do	300,000	
1868—September	St. Helen	Washington and Oregon	300,000	
1871—October	Peshtigo	Wisconsin	1,280,000	1,500
1871—October		Michigan	2,000,000	
1876—(?)	Big Horn	Wyoming	500,000	
1880—September	Bagot	Quebec	288,000	
1881—September	Michigan	Michigan	1,000,000	138
1891—May	Comstock	Wisconsin	64,000	
1894—July	Phillips	do	100,000	13
1894—September	Hinckley	Minnesota	160,000	418
1902—September	Columbia	Oregon and Washington	604,000	18
1903—April-June	Adirondack	New York	450,000	
1908—August	Fernie	British Columbia	64,000	9
1908—September	Chisholm	Minnesota	20,000	
1910—August	Great Idaho	Idaho and Montana	2,000,000	85
1910—October	Baudette	Minnesota and Ontario	300,000	42

From this list the Michigan, Hinckley, Columbia, and Great Idaho fires have been selected as a basis for study of the meteorological conditions just prior to their occurrence, to see if the character of the winds fanning the flames might not have been predicted sufficiently in advance to have been of material aid in preventing the losses that took place. Similar studies of conditions just prior to the other historic fires could be made to advantage, but the meteorological data are lacking for the earlier fires, and exact information regarding the dates and areas burned over is not at hand for those of recent date, other than those selected. The Michigan and Hinckley fires occurred in a comparatively level country, with very little, if any, complication in wind movement due to topography, while the Columbia and great Idaho fires occurred in a mountainous region where valley and mountain breezes are the rule rather than the exception.

CONDITIONS PRECEDING MICHIGAN AND HINCKLEY FIRES.

The Michigan fire caused the death of 138 people, and the property loss was estimated to be slightly over $2,000,000. The principal burnt district was in the eastern part of the State between Saginaw Bay and Lake Huron, and this and the adjoining territory constitute what is known as "The Thumb" of Michigan. It was on August 31, 1881, that the fires became alarming, but it was not until September 5 that the great conflagration started its work of destruction. It lasted three days, or until Wednesday, September 7, when heavy rains fell and quenched the flames.

The conditions leading up to the fires are described in Signal Service Bulletin No. 1, as follows:

In September [1881] no penetrating rain had fallen for almost two months. Almost every stream was dry. Many wells had become empty. The swamps had been burned to hard clay by the sun, fiercer in its heat than it had been for years before. The vegetation of the fields and woods had become tinder. The earth was baked and cracked, the heat having penetrated to an unusual depth. Everything was ready to feed the fires when they finally came. Old roots, pine tops, branches, brush heaps, timber, and the parched earth made the fuel for the burning.

The weather maps just prior and during this fire are reproduced in figures 1, 2, 3, and 4.

The Hinckley fire was the smallest in area of the four under consideration, but the loss of life was the greatest of any but one in the history of forest fires in the United States and Canada. It occurred on Saturday, September 1, 1894, and was confined to Pine, Carlton, and Mille Lacs

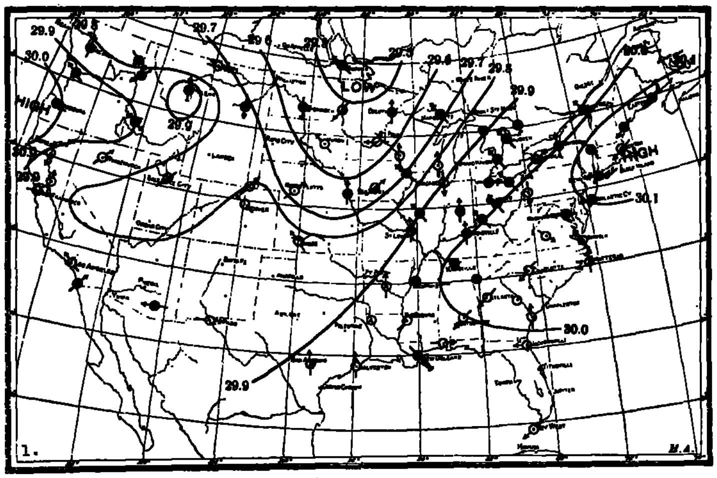

FIG. 1.—Michigan fire. Map for Sept. 4, 1881, 7 a. m., Washington time. —— isobars; ○ clear; ◐ partly cloudy; ● cloudy; R rain. Arrows fly with the wind.

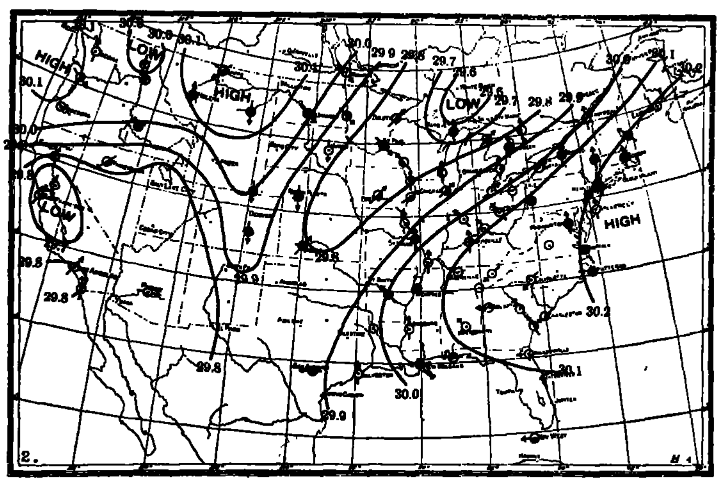

FIG. 2.—Michigan fire. Map for Sept. 5, 1881, 7 a. m., Washington time. —— isobars; ○ clear; ◐ partly cloudy; ● cloudy; R rain. Arrows fly with the wind.

Counties, which are situated in the eastern part of Minnesota nearly midway between St. Paul and Duluth. The Rev. William Wilkinson published in 1895 the history of this fire, and from his book the conditions leading up to it are given as follows:

These conditions, i. e., great lack of rainfall, high temperature, dry air, and light winds, were persistent for a period of nearly four months, resulting in parched earth, crops destroyed, vegetation of all kinds dried up, and down timber and brush but tinder for the match. Fires had been started in August in various places throughout the timber regions of Minnesota, Wisconsin, and Michigan, and smouldered or sprung into life as the winds arose. Such was the conditions up to the 1st day of September, which ushered in high winds, that fanned the fires into fierce flames, themselves also creating a strong upward draft, increasing with the increase of the fierceness of the fires which caused such destruction of life and property.

The distribution of pressure causing the winds that "fanned the fires into fierce flames" is shown in figures 5 and 6.

CONDITIONS PRECEDING THE COLUMBIA FIRE.

The next historic fire occurred on the west side of the Cascade Mountains in the neighborhood of Portland, Oreg., in 1902. According to compilations by the Forest Service there were 18 lives lost in this fire, and property amounting to $12,767,100 was destroyed. The fires were worst between September 8 and September 12, the latter

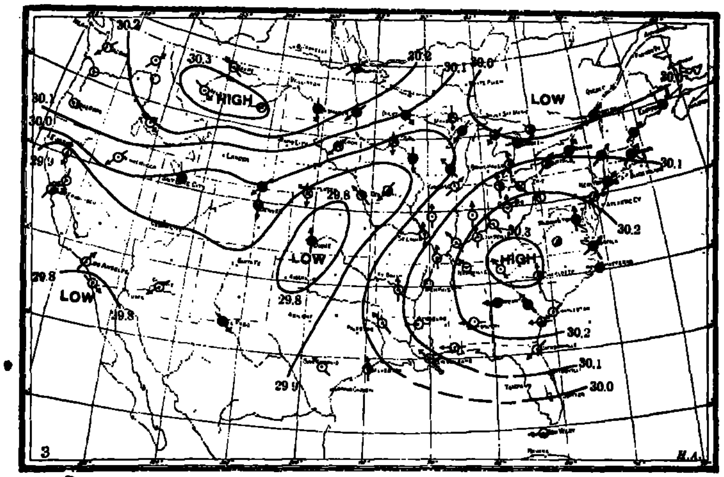

FIG. 3.—Michigan fire. Map for Sept. 6, 1881, 7 a. m., Washington time. —— isobars; ○ clear; ◐ partly cloudy; ● cloudy; R rain. Arrows fly with the wind.

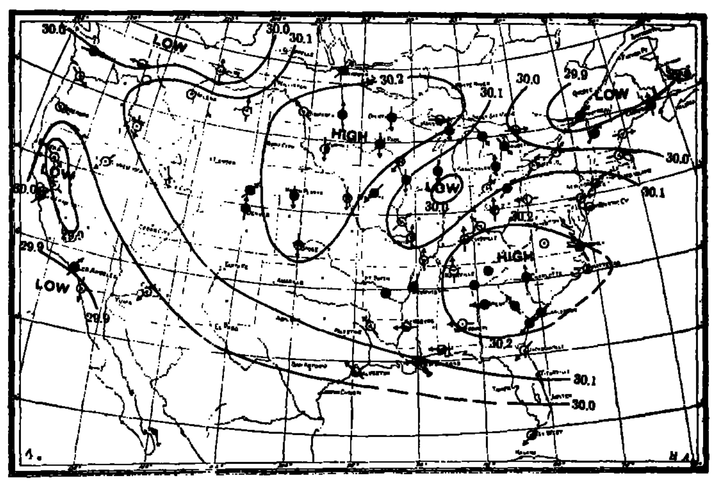

FIG. 4.—Michigan fire. Map for Sept. 7, 1881, 7 a. m., Washington time. —— isobars; ○ clear; ◐ partly cloudy; ● cloudy; R rain. Arrows fly with the wind.

date being known as the "dark day" in nearly all the region west of the Cascade Mountains. Previous to this time fires had been smouldering in many places in western Washington and western Oregon.

In an unpublished manuscript by Mr. William T. Cox, of the Forest Service, he describes the conditions preceding this fire as follows:

The past season [1902] was particularly favorable to forest fires. Not only was the summer very dry but the two preceding summers were wet in May and June, thus interfering with the burning of slashings, and allowing an unusual amount of débris to accumulate. In the early part of September the wind blew from the east most of the time. An east wind after it gets west of the Cascades is ready to absorb any quantity of moisture, so the forest was soon in the condition of tinder.

The temperature and rainfall departures at Portland, Oreg., for the six months preceding the fire are shown in the following table:

Month.	Temperature.	Rainfall departures.
1902.	°F.	Inches.
March	+1.3	+0.61
April	−2.1	+ .66
May	−0.7	− .17
June	0.0	− .98
July	−1.2	+1.22
August	+0.9	− .21

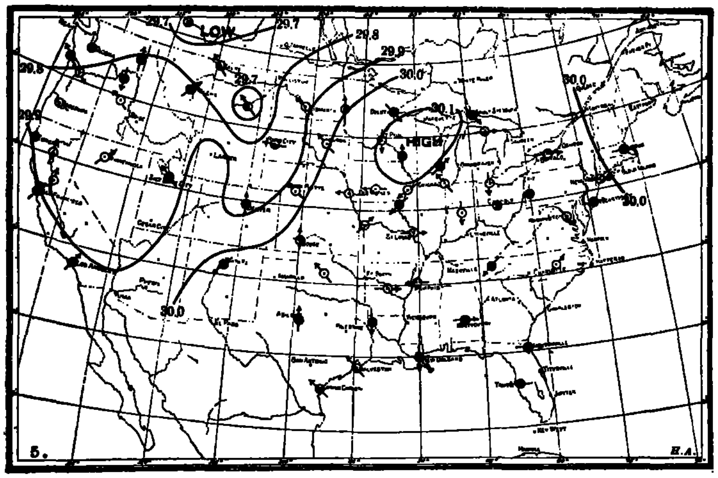

FIG. 5.—Hinckley fire. Map for Aug. 31, 1894, 8 a. m., 75th mer. time. —— isobars; ○ clear; ◑ partly cloudy; ● cloudy; R rain. Arrows fly with the wind.

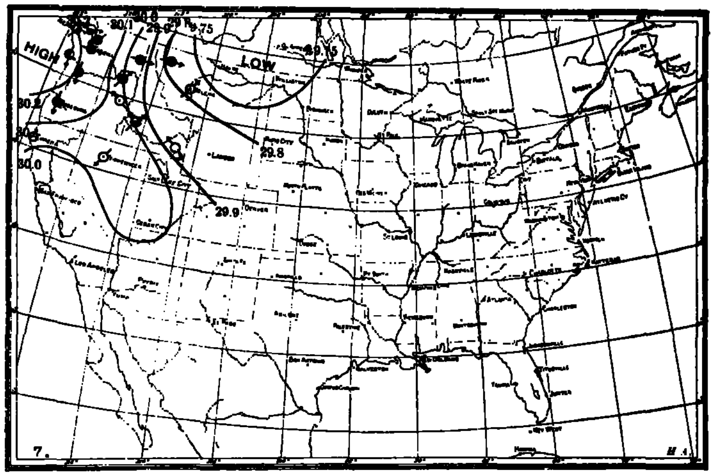

FIG. 7.—Columbia fire. Map for Sept. 7, 1894, 8 a. m., 75th mer. time. —— isobars; ○ clear; ◑ partly cloudy; ● cloudy; R rain. Arrows fly with the wind.

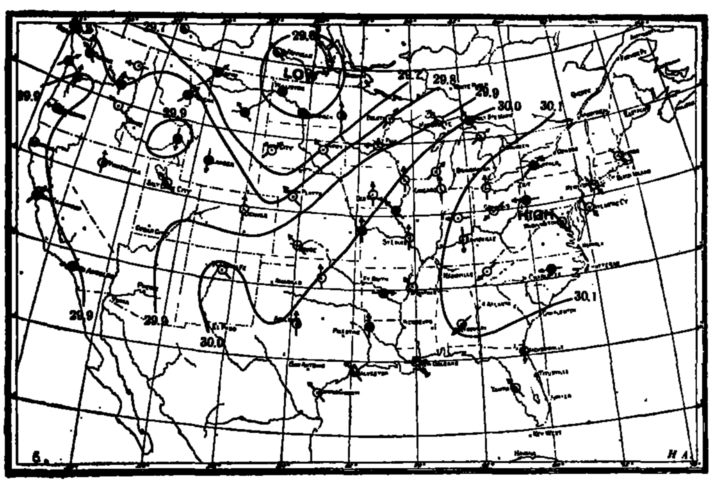

FIG. 6.—Hinckley fire. Map for Sept. 1, 1894, 8 a. m., 75th mer. time. —— isobars; ○ clear; ◑ partly cloudy; ● cloudy; R rain. Arrows fly with the wind.

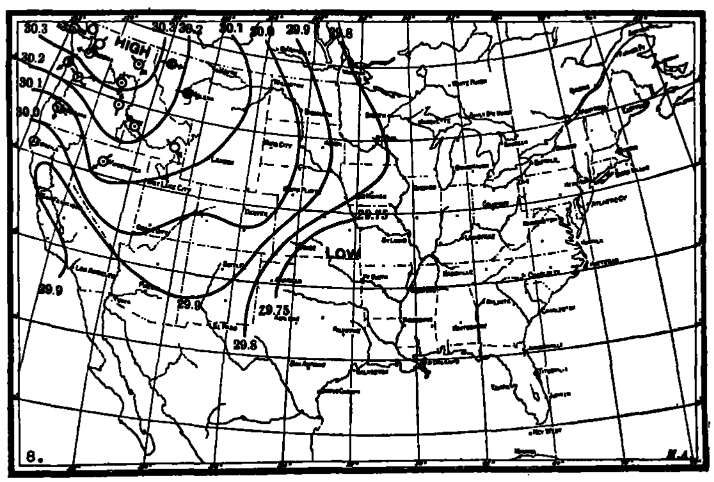

FIG. 8.—Columbia fire. Map for Sept. 8, 1902, 8 a. m., 75th mer. time. —— isobars; ○ clear; ◑ partly cloudy; ● cloudy; R rain. Arrows fly with the wind.

Figures 7 to 12, inclusive, show the meteorological conditions prevailing from September 7 to 12, 1902, inclusive, which is the period just before and during the time the greatest damage was done.

THE GREAT IDAHO FIRE OF 1910.

The worst season for forest fires in recent years was in 1910, which is credited with two of historic character in Forest Service Bulletin No. 117. One of these occurred in August, and is known as the Great Idaho Fire, and the other in October, and is called the Baudette Fire. The former burned over about 2,000,000 acres in Idaho and Montana and the latter swept through 300,000 acres of timberland in Minnesota and Ontario. Of the 127 persons who perished in these two fires, 85 lost their lives in Idaho and Montana and 42 in Minnesota and Ontario.

For reasons previously given the Baudette fire is not considered in this article, but there is sufficient information at hand about the Great Idaho Fire to analyze the conditions that prevailed at that time. The fires in 1910 were most destructive in the Cœur d'Alene and St. Joe Valleys in Kootenai, Cœur d'Alene, and Shoshone Counties in Idaho, but they were numerous elsewhere in the Northern Rocky Mountains and also in the Cascade Range of Mountains. Fires occurred in May and June in the drainage areas of the Cœur d'Alene and St. Joe Rivers, but there were no large fires in this section until July 9, when one broke out back of Turner Bay on Coeur d'Alene Lake. From this time on one fire after another was reported by the forest patrols until as many as 15 large fires were burning at one time. They were kept under fair control until August 20, when a hot, high wind from the southwest began to blow, which quickly spread the fires beyond the trenches, and they burned so furiously nothing could be done to stop them. By the evening of the 21st the weather became more favorable, and as the fires had practically burned themselves out no great damage was done after this date, although they kept burning until about September 1, when rain fell and put them out.

From information received from the officials in charge of the local offices of the Weather Bureau in Helena, Mont., and Boise, Idaho, the weather conditions leading up to the great Idaho fire were as follows: The snowfall during the winter of 1909–10 was less than usual, and the heaviest deposits were in February. The following March was a very warm month, and the snow by the 1st of April had disappeared at high elevations and in forests where generally snow is found until June. The following months were warm and the rains were light, which caused the humus in the forest and the grass on the hills and mountains to dry out much earlier than usual. Only about 35 per cent of the normal amount of rain fell in June, and by July the forested sections were generally as dry as tinder, and fires would start on slightest provocation.

The following table shows the departures from the normal temperature and precipitation in northern Idaho and western Montana from March to April, 1910, inclusive:

Month.	Temperature departures.		Precipitation departures.	
	Northern Idaho.	Western Montana.	Northern Idaho.	Western Montana.
1910.	° F.	° F.	*Inches.*	*Inches.*
March	+5.5	+7.4	+0.36	−0.08
April	+4.3	+5.6	+ .60	− .13
May	+2.9	+2.3	+ .02	− .43
June	− .4	+1.7	−1.18	−1.29
July	+1.5	+2.0	− .76	− .70
August	−2.5	−2.1	− .72	+ .02

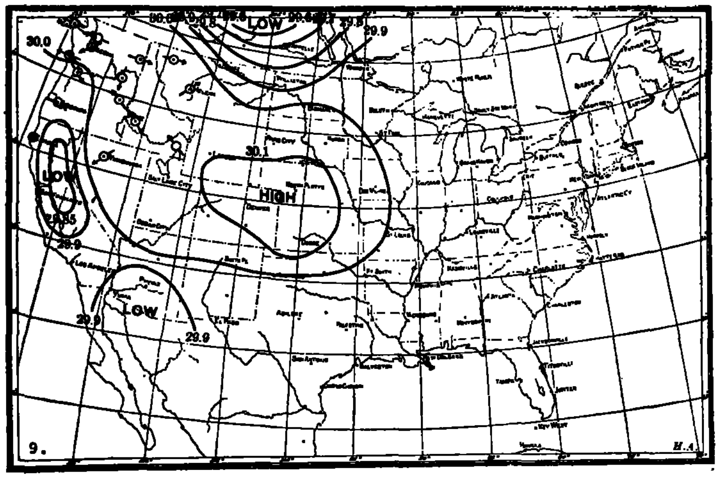

FIG. 9.—Columbia fire. Map for Sept. 9, 1902, 8 a. m., 75th mer. time. ▬ isobars; ◯ clear; ◑ partly cloudy; ● cloudy; R rain. Arrows fly with the wind.

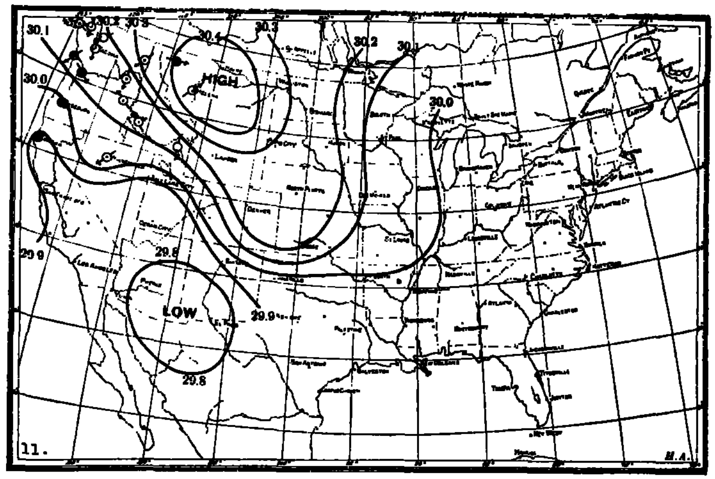

FIG. 11.—Columbia fire. Map for Sept. 11, 1902, 8 a. m., 75th mer. time. ▬ isobars; ◯ clear; ◑ partly cloudy; ● cloudy; R rain. Arrows fly with the wind.

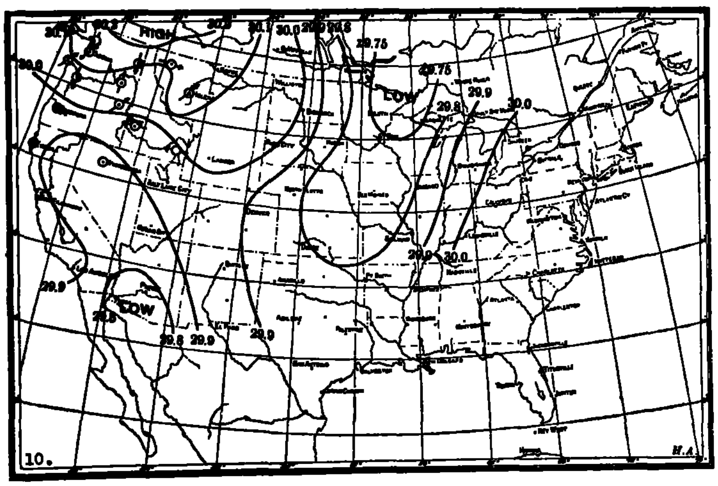

FIG. 10.—Columbia fire. Map for Sept. 10, 1902, 8 a. m., 75th mer. time. ▬ isobars; ◯ clear; ◑ partly cloudy; ● cloudy; R rain. Arrows fly with the wind.

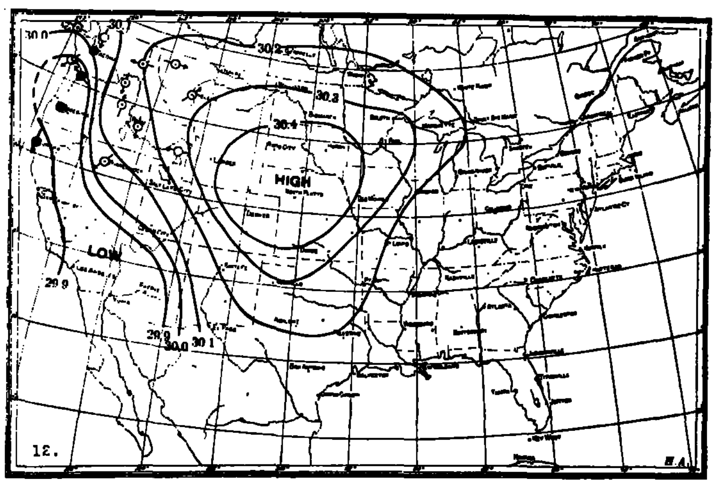

FIG. 10—Columbia fire. Map for Sept. 12, 1902, 8 a. m., 75th mer. time. ▬ isobars; ◯ clear; ◑ partly cloudy; ● cloudy; R rain. Arrows fly with the wind.

Figures 13, 14, and 15 illustrate the meteorological conditions just preceding and during the period the fires were beyond control.

GENERAL CONCLUSIONS.

One striking feature of all large forest fires is the strong winds that prevail just before, during, and for a short period after the fire passes a given place.

In the report on the Michigan fire by Sergt. Bailey he quotes from the survivors such expressions as the following: "Fire was driven by strong changing winds that grew to be gales as the flames advanced." "All day Sunday the wind was in the southwest and was very hot. The next day toward noon the wind increased to a dangerous gale, changing to almost a west wind." "The southwest gale that blew the fires into Huron Township was sufficiently strong to prostrate trees 30 feet high and 6 or 8 inches in diameter." "The whirlwind that carried the fire into and through Huron City seems to have hugged the country adjoining the lake coast." "Wind was strong enough to tear the roofs from barns, to throw down log houses, and to lift persons from the ground and hurl them short distances through the air." "The strength of the southwest current may be judged from the fact that in Sherman township it caught up a wagon weighing 1,000 pounds and hurled it 15 rods across a railway track." "It roared like a tornado and gave forth loud explosive sounds that were terrifying."

Similar conditions were described by the survivors of the Hinckley fire in Rev. Wilkinson's book, from which the following remarks are quoted: "By 2 p. m. the wind became a hurricane." "On the day of the great fire the wind blew a gale from the southwest and swept the fire, which seemed formed in a line about 3 miles long, over the town." "The wind was now blowing fearfully." "The wind was blowing a gale, and a terrible noise was heard, as of a great many wagons being driven over a rough road." "Before the fire we could hear a rumbling noise, as if the wind was blowing a gale." "We could hear a peculiar sound, like thunder in the air." "About 5:30 we heard a noise like lumber piles falling." "The wind was blowing a hurricane." "The wind began to blow furiously, while all the time before it was calm." "A gust picked up a woman and carried her about 25 or 30 feet, when she was dropped among some cornstalks."

Mr. J. B. Halm, a Forest Service official, who was on the Cœur d'Alene National Forest at the time of the great fire in 1910, states that:

> The heat from these fires created tremendous drafts which swept whole mountain sides, uprooting every tree. This draft in every instance became a sort of tornado which blew the timber in great whirls from one-fourth to 1 mile in diameter. This wind in many instances was so strong that trees, when uprooted, where thrown several feet uphill from where they grew.

Similar testimony from eyewitnesses is lacking for the Columbia fire, but Mr. Cox in his paper states:

> The wind must have been terrific, to judge by the quantity of timber thrown and the number of branches broken from maple and other trees.

An examination of the weather maps on the dates of the fires shows no conditions sufficient to cause extraordinary winds, and the only conclusion that can be reached is that the fires themselves produced these furious gales, resembling as they did the wind rush attending a thunderstorm or the violent whirl characteristic of the tornado. Every condition was there, except moisture, to produce local thunderstorms or even tornadoes, and the atmospheric movements were probably much the same as those taking place when true sand storms prevail in desert countries, where strong convectional currents cause unstable equilibrium, and whirls are generated that may have a vertical or a horizontal axis.

The convectional currents caused by a forest fire are much stronger than those produced by the sun warming a sandy surface, but the mass of air warmed by a forest fire is generally smaller, and therefore the wind would be more energetic within the field of action and not greatly disturbed elsewhere. That it is not greatly disturbed elsewhere is proven by the maximum wind velocities recorded at near-by places, which are shown in Table 2:

TABLE 2.—*Maximum wind velocities at near-by stations.*

Name of fire.	Maximum wind.	Direction.	Place.	Distant.
	Miles per hour.			*Miles.*
Michigan	25	W	Port Huron	40
Hinckley	20	S. W	Duluth	70
Columbia	24	N. E	Portland	30
Idaho	23	S. W	Spokane	55

Forest fires do not spread nearly as rapidly as the speed of the wind in the neighborhood of the fire would seem to indicate, for if they did they would travel at the rate of 80 miles or more an hour, and that is a preposterous supposition. In the Michigan and Hinckley fires the rate of progression was about 8 miles an hour, and while no data are at hand for the Columbia and Idaho fires it is believed they did not travel much if any more

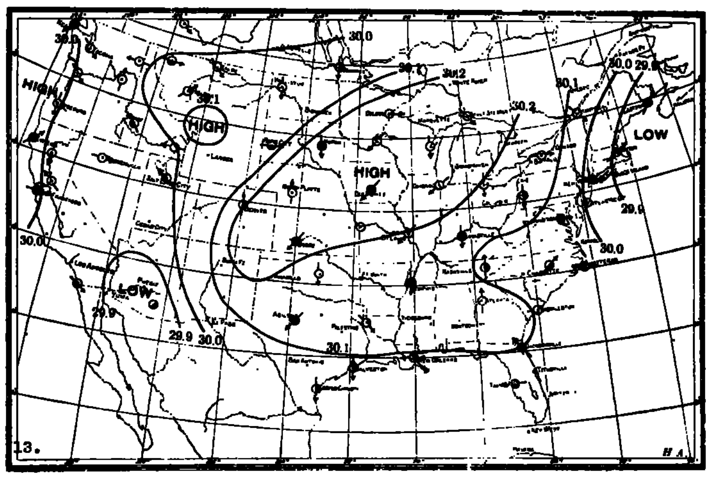

FIG. 13.—Great Idaho fire. Map for Aug. 19, 1910, 8 a. m., 75th mer. time. —— isobars; ○ clear; ◑ partly cloudy; ● cloudy; R rain. Arrows fly with the wind.

rapidly than the others. At times when conditions are exceptionally favorable the rate of progression may be greater, as noted by Sergt. Bailey, who stated, "The flames spread over the parched meadows faster than a horse could gallop." The whirls induced by the convectional currents generated by the fires are translated forward by the mass of air in which they are formed much the same as eddies in a river are carried along by the current, and these eddies at no time move forward more rapidly than does the water surrounding them.

No weather forecaster can predict the speed of the wind in close proximity to a fire, for that, as we have seen, is a local condition depending on the amount of heat created, which in turn causes the convectional currents that disturb the equilibrium of the atmosphere. The translatory movement of the atmospheric mass, however, can be predicted within a reasonable degree of accuracy and the problem then becomes one of determining how rapid the translation of the whole mass of air must be to cause a forest fire to spread beyond control.

The air was remarkably hot and stagnant for a week or more preceding the Michigan fire, except on one occasion about five days before it broke out. The winds on this day, August 31, 1881, were a little stronger than they had been, but not strong enough to cause a general conflagration. A weak, low pressure area was central north of Lake Huron and a thunderstorm developed over lower Michigan which advanced eastward to the Canadian Province of Ontario. The rainfall was light and the wind rush attending the storm caused one fire to increase in size and to spread through several townships. The maximum wind velocity on this day at Port Huron was 42 miles from the south, while on the day of the great conflagration the maximum velocity at the same station was 25 miles from the west. The total 24-hour movement at Port Huron was 233 miles on the day of the small

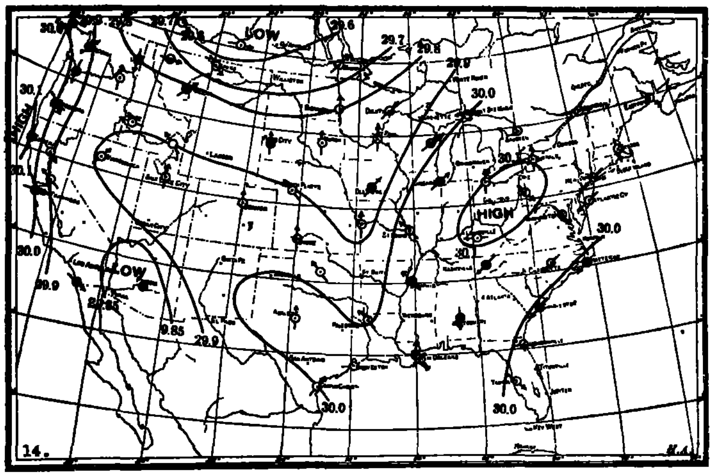

FIG. 14.—Great Idaho fire. Map for Aug. 20, 1910, 8 a. m., 75th mer. time. —— isobars; ○ clear; ◑ partly cloudy; ● cloudy; R rain. Arrows fly with the wind.

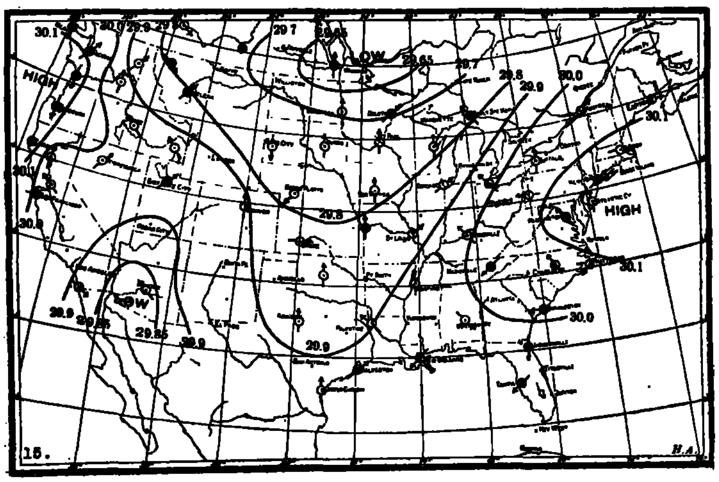

FIG. 15.—Great Idaho fire. Map for Aug. 21, 1910, 8 a. m., 75th mer. time. —— isobars; ○ clear; ◑ partly cloudy; ● cloudy; R rain. Arrows fly with the wind.

fire and 331 miles on the day of the large fire. In the one case the average hourly velocity was 10 miles and in the other 14 miles.

It is not safe to conclude from these data that an average hourly velocity of 10 miles will cause a fire to spread over a small area, and 14 miles will cause one to spread over a large area, for in the first place the average velocity might be quite different from the actual velocity when the fires were spreading most rapidly, and in the second place the direction of the wind might materially change the result. If the direction was such as to cause a back fire it would operate to check spreading, or if the direction was toward an open country there would be no fuel for the flames, and consequently the fire instead of spreading would be held back.

For a week preceding the Hinckley fire the air was also remarkably stagnant, the greatest 24-hour wind movement at St. Paul, Minn., being 149 miles on August 28, 1894, which is an average of only 5 miles an hour. On the day of the fire the 24-hour movement at the same station was 219 miles, which is an average of 9 miles an hour. This is about the same velocity as that which caused the first Michigan fire to spread over several townships, and it is believed with other conditions favorable a velocity of about 10 miles an hour is an extra hazardous wind for spreading forest fires in a level country, and that whenever they are expected those interested in forest fire protection should be advised as far ahead of their coming as possible. It then becomes a matter for the forest officials to judge whether the direction of the expected winds is such as to make it necessary for them to redouble their efforts in checking the spread of the flames, or whether the increase in the velocity will be offset by a change in direction and the fires abate rather than increase in size. This point is obviously one that the forecaster could not be expected to know about, but it is a vital one in interpreting a wind forecast, whether made for mariners or landsmen.

It is quite probable that the Michigan and Hinckley fires could easily have been prevented by modern fire-control methods, but at the time they occurred there were no laws to stop the burning of slashings, which were burned whenever and wherever owners saw fit, and there were no organized fire patrols or any systematic efforts made to check the spreading of dangerous fires. It is reported that the settlers in Michigan were busily engaged in clearing their land with local fires on the very day the great conflagration started and destroyed everything they had except the bare land. To a slightly less degree the same conditions prevailed in Minnesota at the time of the Hinckley fire, but the Columbia fire and especially the Great Idaho fire occurred under entirely different conditions.

When the Columbia fire took place the Forest Service had just been organized and the timbermen in the North Pacific States were beginning to realize the necessity of taking systematic measures to prevent the destruction of the standing timber by fire. Conservation forces then were not organized as they are now, and it is possible the Columbia fire would not have gained the headway it did under the present system of fire control, but the weather conditions leading up to it were almost as bad as they could be and no worse are likely to be met in the future.

Mr. Cox in his description of the conditions leading up to this fire mentioned the fact that the wind blew from the east and that this wind after it gets west of the Cascades is ready to absorb any quantity of moisture. His statement is corroborated by the charts illustrating the meteorological conditions prevailing at that time, and an explanation is necessary to show why an east wind is so dry and dangerous.

The Columbia fire occurred at the base of the Cascade Mountains on the west side of the range. The east wind that blew consisted of air overlying for the most part the treeless plateau of eastern Washington which was forced up the east side of the range and down the west side. The elevation of the eastern Washington plateau will average about 1,500 feet, while the elevation of the district where the fire occurred is probably less than 500 feet. Air when forced up a mountain side cools at the rate of 1.6° F. per 300 feet and when flowing down the other side it is being compressed and it grows warmer at the rate of 1.6° per 300 feet. The average altitude of the crest of the Cascades is not far from 4,500 feet. Air overlying the eastern Washington plateau in the early part of September has a normal temperature of about 68° and that was about the temperature prevailing when this east wind was blowing. It ascended about 3,000 feet and descended about 4,000 feet; therefore, if no other complications occurred, it was about 5° warmer when it reached the lower level on the west side of the range. This would make the mean temperature 73° with probably a maximum of 90° and a minimum of 56°.

The amount of water vapor that it is possible for air to contain depends on the temperature. At zero temperature it can contain 0.54 grain per cubic foot; at 30°, 1.97 grains per cubic foot; at 60°, 5.76 grains per cubic foot; and so on, increasing at a rapid rate. As a matter of fact the air seldom contains all the water vapor it is capable of holding and during a hot day in the subarid region of eastern Washington there is only about 40 per cent of the possible amount. It is probable that the humidity was not greater than 40 per cent when the east wind that Mr. Cox mentions was passing over eastern Washington, and when it reached the other side of the Cascade range of mountains and the temperature was increased by 5° as explained in the preceding paragraph, the humidity would be 34 per cent, which indicates there was only about a third of the moisture present that it was possible for the air to contain. Under these conditions evaporation takes place rapidly, especially if a fresh breeze is blowing and the desiccating effects of the atmosphere are very great.

Winds of this character are called fœhn winds in Switzerland and chinook winds in the United States. They excite more attention in winter than during the other seasons, for then great quantities of snow are often evaporated in a few hours, and its disappearance attracts the attention of everyone. In some parts of Switzerland it is said fire patrols go quickly from house to house when these winds begin to blow, in order to be sure that the fires have been extinguished, for great conflagrations may easily occur at such times owing to the drying of the wood by the wind.

Owing to the mountainous nature of the country where the Columbia fire occurred, weather data from a nearby station do not reflect the conditions prevailing in the immediate proximity of the fire so well as in the case of the Michigan and Hinckley fires where the country is comparatively level, but as no other data are available it is necessary to use those for Portland, Oreg., a station some 30 miles or so to the west of the fire.

For three weeks preceding this fire the atmosphere was remarkably quiet, with the usual summer northwest monsoon winds prevailing. During this time the greatest 24-hour wind movement was 183 miles on September 5 and the maximum wind velocities for each 24 hours did not exceed 19 miles, and generally they were not greater than 12 or 14 miles. On September 8 the wind increased and the direction changed to northeast. The maximum velocity on that day was 24 miles and the total movement was 253 miles. This was the wind that caused the fires to spread beyond control. It will be noticed that the average hourly velocity was between 10 and 11 miles an hour, which approximates the velocities prevailing when the Michigan and Hinckley conflagrations were under good headway. Also the maximum velocity was about the same as during the other two fires. There was a vast difference, however, in the character of the wind as regards dryness, and there might have been a greater difference in velocity due to the ruggedness of the topography in the vicinity of the Columbia fire. Also the winds during the Columbia fire were blowing out from a high pressure area and those at the time of the Michigan and Hinckley fires were blowing in toward the center of a low pressure area, which denotes independently of topography that they were ascending winds in the latter case and descending in the former. Just what bearing this fact would have in propagating forest fires the writer does not know, but it is a matter to be considered in questions of this character.

The most destructive fire from a property loss standpoint was the great Idaho fire which broke beyond control on August 20, 1910. This fire took place after laws had been passed regulating the burning of slashings, providing penalties for leaving camp fires burning and when an efficient forest patrol was in operation, and it shows that the hand of man is powerless to stay the forces of nature when she asserts herself in all her might. Undoubtedly this conflagration would have been 10 times worse if it had not been for the efficient fighting done to prevent the fires spreading before the day of the great conflagration.

There were no fœhn or chinook winds when this fire broke out, for the air was blowing up the mountain side and toward a low pressure area central over the Canadian northwest. Also, the weather map the day before gave no indication that the winds would be any stronger than they had been on the preceding days, and, in fact, the weather map on the morning of the fire did not show that any stronger winds should be expected than on several occasions during the last half of July and during the first two decades of August.

The great conflagration was brought about by winds which the records at Spokane, the nearest station, show did not exceed 23 miles an hour. They spread 15 or more comparatively large fires into one great fire. Wind forecasts, to have been of benefit in this case, should have been made to cover the minor fires, and this was impossible, as many of them occurred in canyons where the controlling factors were mountain and valley breezes. As explained before, mountain and valley breezes are of local character and the time of their beginning and ending as well as their force and directions are features that behave with almost clock-like regularity, and therefore are well known to the man on the ground, but not to the district forecaster.

That the wind would increase on August 20, 1910, to cause the breaking beyond bounds of a forest fire could not have been foreseen on the morning of August 19; it was faintly indicated on the evening of the 19th, and sufficiently pronounced on the morning of the 20th to warrant a warning being issued, but then it was too late to have done any good. Furthermore, it was only in that particular section that winds of more than ordinary strength could be expected, and for this reason the district forecaster ought to be kept advised regarding the localities where there is the greatest danger of forest fires spreading beyond control, for then he could concentrate his attention on those places.

As the time is short in which the forecaster must act, and it is the desire of the Weather Bureau that the information available be disseminated so as to do the greatest good to the greatest number, it is evident that wants and localities should be designated in detail so that he can give his undivided attention first to those matters that are most pressing, and then to the others in the order of their importance. After a warning is issued it is of equal importance that it be disseminated as quickly as possible, for failures to profit thereby are as apt to occur through the late receipt of the warning as they are in any other way.

In conclusion, it is thought that an intelligent use of the facilities of the Weather Bureau would be of assistance to those engaged in fighting forest fires, but where forests are situated near the sea, or in a mountainous country, there are so many local controls to wind movement that much will have to be left to the man on the ground. The subject is certainly worthy of further study which it is believed should be jointly done by specialists in both branches of the work, that each might have a better understanding of the limitations of the other in reaching their conclusions.